

The University of Chicago

THE WORK DECREMENT AS
AFFECTED BY THREE KINDS
OF MEANINGFULNESS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

1937

By
MARY FRANCES ROBINSON

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BY MARY FRANCES ROBINSON

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Interest in repetition as a cause of decrement in mental work has been manifested for a number of years. Dodge (6) called attention to its importance in 1917 in his *Laws of Relative Fatigue*, and several experimental investigations have been devoted to it.

Thorndike (20) noted that subjects who were permitted a choice in their responses of numbers from 0 to 9 showed a rather surprising avoidance of immediate repetition. Telford in his later elaboration of the same experiment obtained similar results.

Poffenberger (15) found that the four tasks, continuous addition, judgment of compositions, completion of sentences, and intelligence tests, were productive of decrement in the order named. He attributed the decrement to the continuous exercise of a single function but remarked that opportunity for frequent short rests in the course of work may prevent decrement.

In 1926, Robinson and Bills (16) reported their rigidly quantitative study of the effect of repetition. Requiring their subjects to write continuously such letter sequences as *ababab*, they investigated five degrees of homogeneity-heterogeneity. As judged by either the first minute or the tenth minute of the work period, the results under the five conditions are strikingly clear—the greater the degree of homogeneity and hence of repetition, the greater the work decrement. Similar results were obtained with letter naming.

In marked contrast to these quantitative investigations are the Gestalt studies of fatigue. Karsten, working under

¹ From the Psychological Laboratory of the University of Chicago. The writer is greatly indebted to Dr. Arthur G. Bills, who directed the research.

Lewin (12), pointed out the limitations of the principle of repetition. She showed that it is not always a cause of mental fatigue, since one child voluntarily opened and shut a door eighty-two times. Moreover, after 'psychic satiation' had occurred in performing such tasks as making continuous strokes with a pencil in the rhythm 3-5 (/// ///), repetitions of the unit were still possible if the unit were changed to 4-4 (//// ///).

Lewin (10) does not offer an alternative principle to repetition as productive of mental fatigue or boredom, but Hoche (8) suggests that the chief cause of boredom (Lange-weile) in any given period is poverty of the content offered.

No other variable in the work materials has been studied with the thoroughness accorded to repetition.

Arai (1) and Painter (14) were interested in difficulty, but since Arai used only one grade of difficulty in each section of her experiment, and since Painter's performance broke down before other grades were tried, their results regarding difficulty as a principle of decrement are not clean-cut.

Much clearer is the evidence regarding the influence of competition among the required responses as found by Robinson and Bills (16) in their study of finger movements in a typewriting task. They found that the use of two fingers alternately or of three in turn was productive of more decrement than the use of one finger in repeated movements. But since the competition belongs to the responses rather than to the stimuli, the second principle of the work decrement is not strictly a second principle of variation in the materials.

For the past few years, investigators of mental work have centered their attention upon problems other than the effect of variations of material. Hence the principle of repetition stands almost alone, though in 1926 Robinson and Bills (16) ended their paper, "Two Factors of the Work Decrement," with the statement: "Other principles are also surely fundamental in the determination of the decrement, and all of them offer rich territory for exploration."

PROBLEM

It is the purpose of the present study to select variables other than repetition, to prepare materials embodying them, and to investigate the effect of the variation upon the course of mental work.

Of the many variables that are doubtless available, three have been chosen: connectedness, associative value, and comprehensibility. All three are familiar. Cattell (5) reported in 1886 that he could see and name words more rapidly when they made up sentences than when they were written separately; McGeoch (13) found that the associative value of nonsense syllables facilitated learning them; and Gates (7) and many others in discussing reading tests have emphasized the importance of accurately measuring comprehension of materials.

In order to be suitable for this experiment, the materials embodying the variables must meet three requirements: (1) they must be capable of two or more degrees of variation; (2) they must not vary as regards the amount of repetition involved, that is, the homogeneity-heterogeneity factor must be held constant; (3) they must be of such nature that responses can be made and recorded at comparable rates throughout the work period. The materials used will be described in detail for each experiment.

Apparatus

The apparatus was an electrically driven kymograph, furnished with two telegraph keys connected with metal points that marked on a moving waxed paper tape. The subject responded vocally. The experimenter pressed one of the keys at each response, and an assistant recorded errors with the other key.

Procedure

The procedure was kept highly uniform. The subject sat with his back to the apparatus and to the experimenters. The same general directions were always given: "This is a test of both speed and accuracy. You should try to do two things: (1) read the selection in as short a time as possible, (2) make as few mistakes as possible. If you make a mistake, go right on."

The amount set was employed consistently. Bills and Brown (3) found it distinctly more efficient than the time set, and it would seem to have special advantages in studies of varied materials. The criteria were speed and accuracy.

Equalization of practice was secured by having a preliminary period in each experiment in which all the materials to be used later were given equal representation, and by employing all the permutations of temporal order an equal number of times. In order to differentiate practice effects from fatigue effects, Bills's simplification (2) of the Thorndike (20) method was employed. Each day's task was made up of a certain number of equal divisions or units. The last unit for the day presumably combines the maximum practice effect with the maximum fatigue effect (complicated, of course, under the amount set with end spurt). A repetition of the unit the next day presumably represents the maximum practice effect with the fatigue eliminated. The difference between them is taken as the work decrement.

In order to ascertain the significance of the decrements, the formula for correlated variables was employed throughout the experiments:

$$\sigma_D = \sqrt{(\sigma_{av.1})^2 + (\sigma_{av.2})^2 - 2r\sigma_{av.1}\sigma_{av.2}}$$

To be reliable, a difference must exceed its standard error by a ratio of 2.7 or more.

EXPERIMENT I

Connectedness

The first and most extensive experiment concerned the effect of varying degree of connectedness upon the course of mental work.

Materials

A narrative was chosen as representing the highest degree of connectedness. It was broken up into sentences arranged in scrambled order for the second degree and into words in scrambled order for the lowest degree. In order to enable the responses to proceed at comparable rates, all the words were monosyllables of three letters each. They were written backward. It was the subject's task to reverse mentally the letters of each word and to pronounce the word aloud. A sample sentence will make clearer the nature of the task: "eht yad saw toh." This, of course, was to be read, "The day was hot." No capital letters or marks of punctuation were used, but the word *dot* (*tod*) was placed at the end of each sentence, so that the task Sentences would not involve special confusion. The twelve-hundred-word narrative was made as melodramatic as three-letter words and the writer's limitations would permit.

For the second day's task a sequel to the narrative was prepared, which was broken up in like fashion into sentences and into words for the other grades of material.

Procedure

The conditions of the experiment demanded five days of work of each subject. These were the days of the school week, Monday through Friday. Monday was always devoted to practice, which was divided into two parts, a short preliminary period in which directions were given and words and sentences were tried out, and a longer period in which all the vocabulary to appear later in the regular tasks was presented, partly as separate words, partly in sentences, partly in narrative form (though not as given later). The materials for practice, as well as those for the other tasks, Words, Sentences, and Narrative, were divided into eight units of 150 words

each. The end of the unit was not apparent to the subject, since no break appeared in the work, but it was marked on the tape by the assistant who recorded errors. The next day at the beginning of the work period, two more units of the task were given. This work was called, for convenience, the *Sequel*. A typical schedule for a week is as follows:

Monday	Tuesday	Wednesday	Thursday	Friday
Preliminary practice Practice	Practice sequel Words	Words sequel Sentences	Sentences sequel Narrative	Narrative sequel

Since there were three kinds of tasks, there were six permutations of the temporal order. Ninety-six subjects made possible sixteen repetitions of each order. They were junior college students who were not aware of the purpose of the experiment.

Results

Figures 1 and 2 show the work curves for speed and accuracy respectively.

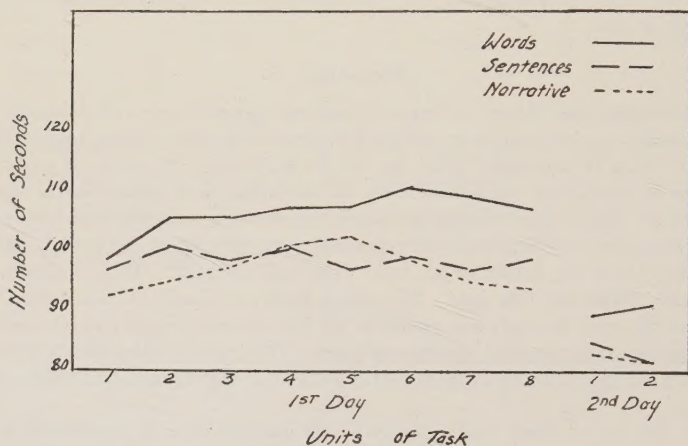


FIG. 1. Average time in seconds per unit of task for the three degrees of connectedness.

The chief interest in the experiment lies in the decrements, which are measured by the difference between the last unit of the first day's task and the first unit given on the succeeding day. All three grades of material show considerable decrement in speed. In the case of Words, it is 16.85 sec. with a standard error of 1.12; with Sentences, it is $14.52 \pm .83$; and with Narrative, 11.09 ± 1.07 . The difference between the

decrements of Words and Sentences is $2.33 \pm .56$. Words and Narrative show a difference of 5.76 ± 1.46 , and Sentences and Narrative, a difference of 3.43 ± 1.20 . These differences are all significant, the critical ratios being 4.2, 3.9, and 2.9, respectively.

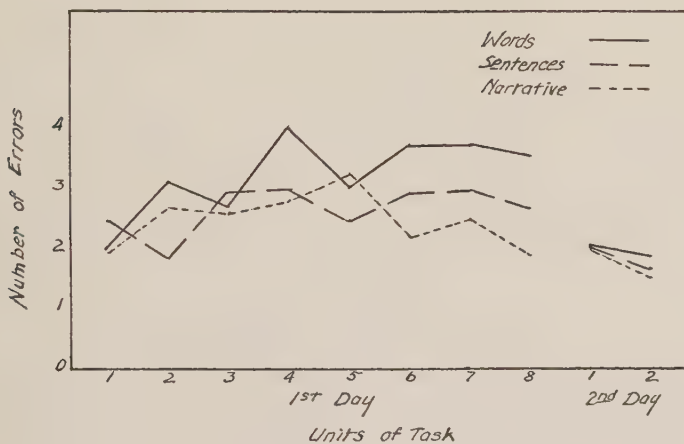


FIG. 2. Average number of errors per unit of task for the three degrees of connectedness.

With the criterion of accuracy, there is a huge decrement for Words, $1.21 \pm .161$; for Sentences one about half that size, $.60 \pm .23$; and for Narrative, none at all. The differences between the decrements are not very large for Words and Sentences ($.62 \pm .35$) or for Sentences and Narrative ($.69 \pm .32$), but the extremes of connectedness, Words and Narrative, have a considerable difference ($1.30 \pm .39$), which is highly reliable.

Results under the two criteria are more easily compared when both are reduced to percentages. The score for decrement in each case is divided by the score for the period of the greatest efficiency, that is, the first unit of the second day's task. Speed shows a decrement of 18.8 percent with Words, 17.3 percent with Sentences, and 13.4 percent with Narrative. The decrements for accuracy are more striking—51.9 percent with Words, 28.8 percent with Sentences, and none with Narrative.

Materials of the three degrees of connectedness show differences not only in the decrements but also in the levels of work efficiency, in spite of the fact that all three tasks are constructed of precisely the same words. An average of 106.07 sec. was required for each unit of Words, while 98.59 sec. sufficed for Sentences, and 96.80 sec. for Narrative. An average of 3.26 errors was made with Words, 2.67 with Sentences, and only 2.49 with Narrative.

How are these differences to be accounted for? Is it possible that with disconnected material irrelevant activities interrupt work and produce a decrement? And is it possible with connected materials that these activities are prevented from arising or are suppressed by an activity that forwards work and reduces decrement?

Subjects' General Behavior

No introspections were required of the subjects. A few of their spontaneous remarks were jotted down, however, as well as occasional observations made by the experimenter.

With the task Words, general restlessness was often noted. F. B. remarked, "I couldn't keep my mind on it today." Many errors were made with *was* and *saw*. C. R. kicked the wall during the last half of the work. The assistants reported that J. P. kicked the wall and swore.

With Sentences, also, the subjects often confused *was* and *saw*. There was more restlessness in the early part of the task than in the latter part. F. M. said, "I couldn't get the drift of some of this."

With Narrative, several subjects blocked before *ebb* and *lea*. S. R. laughed repeatedly. M. J. (one of the fastest workers) read 'with expression.' C. E. (one of the slowest workers) paused at the ends of sentences.

Conclusions

1. The task of reading three-letter words written backward is productive of reliable decrements with both criteria and with all degrees of connectedness, except that accuracy shows none with Narrative.

2. As judged by the criteria of speed and accuracy, connectedness of materials bears an inverse relationship to the decrement developed in the task.

3. With both criteria, connectedness results in three distinct work levels, the level of least efficiency occurring with discrete materials, the level of greatest efficiency, with the most highly connected materials.

4. In general, connectedness affects the activities that occur in mental work in such a way as to facilitate work and to reduce decrement.

Two questions seem to demand immediate investigation: (1) With discrete materials, may mental work be impeded and the decrement increased by irrelevant activities permitted or stimulated by the work itself? In other words, will variations in the associative value of the separate stimuli affect the course of mental work? (2) With connected materials, is it possible to discover the nature of the facilitating activity? Is it dependent in any way upon comprehensibility?

EXPERIMENT II

Associative Value

The effect upon the course of mental work of the associative value of the separate bits of the materials (discrete stimuli) was investigated by means of three short experiments, in one of which the materials were verbal; in one, pictorial; and in one, numerical.

VERBAL MATERIALS—WORDS IN CODE

Materials

The materials were made up of three sets of monosyllables written in code, thirty-two in each set. In one set were nonsense syllables, such as *bramm*, *sab*, *plor*; in one, connectives and auxiliaries, such as *could*, *for*, *here*; and in one nouns and adjectives, such as *slang*, *car*, *date*. The lists were matched, word by word, for number of letters.

In order to secure objective evidence as to their differing in associative value, the three sets were presented to several junior college students prior to the experiment. Their judgments were unanimous that the Nonsense Syllables had the fewest associations and the Nouns and Adjectives most. After the experiments, the words were given in scrambled order to the subjects themselves individually in a free association test. The number of associations for each word was recorded, and the totals were averaged for each list. The average associative value per word of Nonsense was 2.25; of Connectives, 3.52; and of Nouns, 6.36.

The associations varied, of course, with the individual, but certain types of response appeared repeatedly. With Nonsense Syllables there were many rhymes, some of them coming after a fairly long pause. For example, *bram* was followed by 'Sam, tam,' and *sab* by 'tab, blab.' With many Connectives a frequently associated word was given; for example, *could* elicited 'go, could come'; and *for*, 'him, for me.' There was more variation with Nouns. *Slang* was followed by 'bad habit, English class'; *car*, by 'gas, oil, tire, wind-shield.' After *kiss* one girl said 'moonlight' quickly, then stopped and blushed.

The code employed was simply the substitution of digits for the letters of the alphabet, taken in order, 1 for *a*, 2 for *b*, and so on. A copy of the code in large type was fastened on the wall just opposite the subject so that he could look at it at will. In his hands was a card with groups of digits typed upon it, each group constituting a word. His task was to substitute letters for the digits, saying the letters aloud and then pronouncing the word.

Procedure

The conditions of this experiment, as of the former, demanded five days of work of each subject. Monday was always devoted to practice which was divided into two parts, a short preliminary period in which directions were given, all the words pronounced, and a few words in code attempted, and a longer period of actual practice upon all the words used in the regular tasks. Each task consisted of four repetitions of the thirty-two words written in a different order each time. The end of each of these four task units was marked on the tape by the assistant who recorded errors. The next day at the beginning of the experimental period, another unit of the same task was given. This unit was called for convenience the *Sequel*.

Since there were three grades of task, there were six permutations of temporal order. Thirty subjects (junior college students) made possible five repetitions of each order.

Results

The work curves for speed and accuracy are given in Figs. 3 and 4.

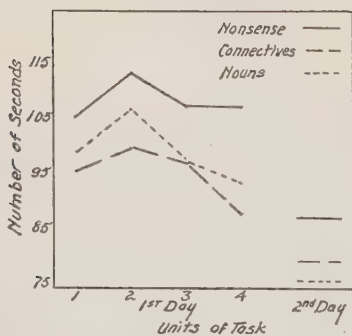


FIG. 3. Time in seconds, verbal materials.

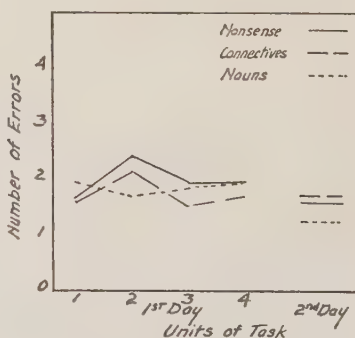


FIG. 4. Number of errors, verbal materials.

With speed as criterion, the decrements for all three materials are highly reliable. They are 20.06 sec. with a standard error of 2.52 for Nonsense, 8.79 ± 1.47 for Connectives, and 17.17 ± 2.91 for Nouns. It is interesting to note that the decrements for the highest and lowest degrees of associative value are very much alike. They show a difference of only 2.89 sec., a figure so low that it is quite unreliable. On the other hand, the decrement for Connectives is 11.27 sec. less than that of Nonsense and 8.38 sec. less than that of Nouns. Both of these differences have high reliability.

In terms of errors, the decrements are .37 for Nonsense, 0 for Connectives, and .74 for Nouns. All three decrements are unreliable, hence their apparently great differences are not significant.

When measured in terms of percentages, the fatigue effect in seconds is 22.9 percent for Nonsense, 11.0 percent for Connectives, and 22.4 percent for Nouns. In errors, it is 23.1 percent for Nonsense, 0 percent for Connectives, and 60.2 percent for Nouns. As has already been pointed out, the error scores are so variable that these figures are more imposing than significant, yet it is interesting that they show the same trends as the time scores.

The levels of work, represented by the average score per task unit, also show these trends, that is, scores which signify low efficiency for Nonsense and Nouns as compared with Connectives. For number of seconds the levels are 108.82 for Nonsense, 95.66 for Connectives, and 99.39 for Nouns. For errors, the levels are 2.00, 1.76, and 1.87, respectively.

Subjects' General Behavior

The behavior of the subjects differed greatly with the three types of material. With Nonsense, there seemed to be little 'getting into' the work. The subjects looked around the room frequently, as if they were distracted by whatever went on. They shook their heads over pronunciations and made many errors, though any possible pronunciation was counted correct. With Connectives the work was steady, and few comments were made. May it be that a connecting

word very often used has the significance of a mild Aufgabe, "Go on"? With the Nouns, two girls and one boy stumbled over *kiss* and *date*.

These facts, together with the type of associations given and the objective results of the experiment, suggest to the writer that with Nonsense the subject had little to hold him to his task and hence was easily distracted, and that with Nouns the discrete bits of the task itself offered distraction through the wealth of association aroused. Both these suggestions need confirmation from experimentation with other types of materials.

Summary

Verbal materials of three grades of associative value were read by means of a code. The materials were Nonsense Syllables, Connectives and Auxiliaries, and Nouns and Adjectives. All three tasks developed reliable decrements with time in seconds, and two tasks, Nonsense and Nouns, showed fairly high decrement with errors.

When the differences in decrement were computed in number of seconds, it appeared that both Nonsense and Nouns differed significantly with Connectives but not with each other. None of the differences were significant with the criterion of accuracy.

Both speed and accuracy reveal three distinct levels of efficiency. Work was least efficient with Nonsense, next with Nouns, and most efficient with Connectives.

The results show that, within the limits of this experiment dealing with verbal materials, a very low degree of associative value and a very high degree of associative value are both more productive of decrement than is an intermediate degree.

PICTORIAL MATERIALS—OUTLINE DRAWINGS

Materials

The materials consisted of two sets of one hundred outline drawings, twenty-nine different drawings in each set. One series consisted of symbols and abstract forms, such as *bracket*, *cylinder*, and *plus*, and the other of objects and animals, such as *thimble*, *elephant*, and *kite*. The items in the two series were matched as to the number of syllables required in the responses.

As with the verbal materials, a preliminary test was made to discover gross differences in associative value in the two sets. After the experiment was over, free association tests were given to the individual subjects. The symbols showed an average associative value of 2.52, the Objects of 3.26.²

The drawings in each series were arranged on a large card, ten rows each way. The subject's task was simply to name the pictures in rapid succession in rows, first across the card, then down, then across, and then down. Each complete naming (one hundred responses) constituted a task unit, and its completion was recorded on the tape by the experimenter.

Procedure

The procedure closely followed that of the preceding experiment except that four work days sufficed instead of five. The first day as before was devoted to practice. With Objects, the chief need of practice was to impress the subjects with the fact that (in order to keep the number of syllables the same in the two tasks) they must say *rabbit* instead of *hare*, and *alligator* instead of *crocodile*; but it was necessary to teach a few subjects the symbols for *bracket*, *oval*, *clubs*, and *spades*.

The subjects were twenty-four junior college subjects.

Results

Figures 5 and 6 give the work curves for the two criteria, speed and accuracy.

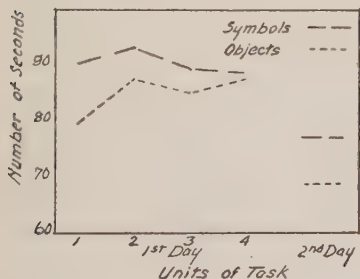


FIG. 5. Time in seconds, pictorial materials.

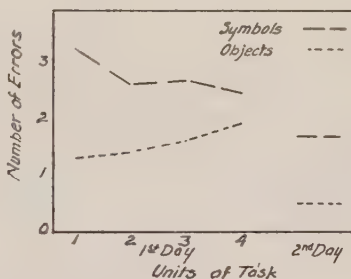


FIG. 6. Number of errors, pictorial materials.

There is a decrement for Symbols of 12.68 ± 2.14 , and for Objects, one of 19.46 ± 2.42 . Both are highly reliable. The difference between the decrements— 6.78 ± 2.87 —is also rather large. It yields a critical ratio of 2.4.

With accuracy also, the decrement is greater for the material having the higher associative value. It is $.79 \pm .47$

² There was much overlapping. Obviously an improvement upon the present plan would be to ascertain the associative value of a large number of drawings and to group them upon that basis.

for Symbols and $1.17 \pm .40$ for Objects. The critical ratio of 2.9 for the latter shows that it is reliably high. The difference between the decrements is not significant.

When the decrements are converted into percentages as in the preceding experiments, they are found to be, with seconds a criterion, 16.7 percent for Symbols and 28.4 percent for Objects, and with errors, 46.2 percent for Symbols and 155.3 percent for Objects. It is interesting that this extraordinarily high error decrement should accrue from the mere naming of perfectly familiar objects and animals, when repetition occurs no oftener with this task than it does with Symbols.

In contrast to all the other experiments in this study, the material with the lower decrement has the work level of lower efficiency. There is an average level of 90.33 sec. for Symbols as compared with 85.16 sec. for Objects. It appears that the relative unfamiliarity of some of the forms and terms made this task actually the more difficult of the two.

Subjects' General Behavior

There were no strong contrasts in the behavior of the subjects with the two types of pictorial material, except for more stumbling and errors in the early part of the task with Symbols and more laughter when errors were made with Objects.

Summary

The task consisted of two sets of outline drawings to be named in rapid succession by the subject. One set consisted of Symbols, one of Objects. When speed was the criterion, both tasks developed reliable decrement, with that for Objects considerably the higher. With accuracy as criterion both tasks again showed decrement, but only Objects to a significant degree. The subjects worked more rapidly, however, with Objects than with Symbols.

The results show that with pictorial material a high degree of associative value tends to produce a high work decrement.

NUMERICAL MATERIAL—DATES AND FOUR-PLACE NUMBERS

Materials

The materials for the third division of the experiment consisted of a list of forty-eight dates important in European and American history and a comparable list of forty-eight four-place numbers without special significance. These lists were prepared with the aid of the instructor in European history, and the dates were those presumably most familiar to the students.

After the experiment was over, lists of the dates and numbers were given to the subjects, who were asked simply to check those that had associations for them, whether or not they were sure they were right. They checked an average of 20.8 dates, and 3.8 numbers.

Each group of digits was written backward. The subject's task was to reverse the order and to read the number properly. Thus the date, 2941, was to be read fourteen ninety-two, and the number, 8631, thirteen sixty-eight. Each task consisted of four complete repetitions of the list of forty-eight numbers, arranged each time in a different order, and on the second day a fifth unit was given, as with the words in the preceding experiment.

Procedure

The procedure closely followed that described for the verbal and pictorial materials. Since only two grades of associative value were used, only four days of work were necessary for each subject. During the practice period all the material was read through once.

The subjects were the twenty junior college sophomores who were recommended as the best history students.

Results

The work curves are given in Figs. 7 and 8.

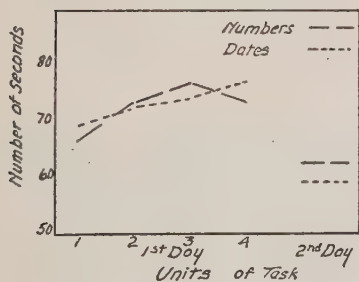


FIG. 7. Time in seconds, numerical materials.

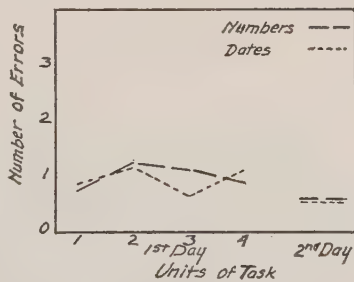


FIG. 8. Number of errors, numerical materials.

In terms of the number of seconds, the decrements are reliable for both degrees of associative value. They are 11.69 ± 1.78 for Numbers and 17.87 ± 1.95 for Dates. The difference between these decrements— 6.18 ± 2.32 —is also reliable, having a critical ratio of 2.7.

The error scores are more variable than would be expected from the uniform nature of the material. More subjects are obviously needed, but no more good history students were available. The decrements are .30 for Numbers and .60 for Dates. These figures are not high enough to be significant, nor is the difference between them significant.

When the decrements are reduced to percentages of the most efficient work unit, the differences between the tasks are striking. With number of seconds, the decrement for Numbers is 18.8 percent and that for Dates is 30.2 percent. With errors, the decrements are 50 percent and 109 percent respectively.

There is very little difference in the work levels for the two grades of associative value. With time, the averages are 75.13 sec. for Numbers and 75.87 sec. for Dates. With errors, the averages are 1.01 and .96, Numbers having the higher average in this instance.

Subjects' General Behavior

No conspicuous differences appeared in the subjects' attitudes toward these tasks during the work itself, but many comments were made afterward about the dates that were recognized. One boy remarked, "I'd get to thinking about what happened during that year, and I'd forget to go on."

Summary

With the criterion of speed, the task of reading numerical material which was written backward produced reliable decrements for the two degrees of associative value that were studied. Moreover, the difference between the decrements was reliable, Dates, the material with more associations, having the higher decrement.

With errors, the decrements were not reliable, but that for Dates was again the larger.

Dates had a much higher percentage of decrement than Numbers with both speed and accuracy. With speed, work was slightly, but very slightly, more efficient for Numbers than for Dates; and with accuracy, this relation was reversed.

The results show that with discrete numerical material, a high degree of associative value is productive of high decrement.

CONCLUSIONS FOR EXPERIMENT II—ASSOCIATIVE VALUE OF DISCRETE MATERIALS

1. When the work materials are discrete and consist of words to be read by means of a code, or of naming drawings in rapid succession, or of reading four-place numbers backward, the decrements developed with the criterion of speed are high enough to be reliable for all degrees of associative value within the limits of this experiment.

2. With the criterion of accuracy, work with these materials is productive of fairly high decrements for all degrees of associative value except for the intermediate degree of verbal material—Connectives—which shows none.

3. Discrete materials of extremely low associative value, exemplified in this experiment only by the Nonsense Syllables, are productive of a greater decrement with both speed and accuracy than are materials with a moderate number of associations.

4. A very low degree of associative value in discrete verbal materials has an adverse effect upon the general efficiency level of mental work.

5. Because of insufficient data, no conclusions can be drawn as to the relative disadvantages of maximum and minimum degrees of associative value. Nonsense showed a higher decrement than Nouns in number of seconds and a lower decrement in number of errors.

6. Discrete materials of extremely high associative value, whether verbal, pictorial, or numerical, are productive of greater decrement in terms of speed and accuracy than are materials of moderate associative value.

7. A high degree of associative value appears to have a somewhat adverse effect upon the general efficiency level of mental work, but the data do not present conclusive evidence.

8. In general, a very low degree and a very high degree of associative value in discrete materials both tend to disrupt mental work and to increase decrement.

No one of these experiments with discrete materials is very convincing in itself. In each one, the work period is short, and the subjects are few. But the fact that all three show the same trends does seem to be significant.

EXPERIMENT III

Comprehensibility

The third experiment is concerned with the effect upon the course of mental work of varying degrees of comprehensibility in connected materials.

Materials

Paragraphs were selected that had three points in common and one marked difference aside from subject matter. The subject matter of each is suggested in its title, Dynamics of Mind, Physiological Limit, and Formal Introductions. All described processes, all had similar structures, all had vocabularies of about equal familiarity. They appeared to differ in comprehensibility, the variable to be studied. Prior to the experiment, they were submitted to several students not serving as subjects who arranged them in order of increasing comprehensibility as they are given above.

After the experiment was completed, the subjects themselves were given mimeographed copies of the three paragraphs, following each of which was written: "The paragraph is (not at all, not especially, somewhat, rather, extremely) clear and easy to understand." They were asked to underline the phrase that most nearly expressed their judgment. For scoring purposes the judgments were given the following values: *not at all*—1, *not especially*—2, *somewhat*—3, *rather*—4, *extremely*—5. When computed for the forty-eight subjects, the averages were 2.6 for Dynamics of Mind, 4.4 for Physiological Limit, and 4.9 for Formal Introductions. It was considered that these judgments showed that the paragraphed differed sufficiently for the purposes of this study.

The paragraphs were written in code much as were the words in the first experiment dealing with associative value. To render the task not too difficult and to avoid penalizing for the longer words, the initial letter of each word was written as usual, and digits were substituted for the other letters.

In making the paragraphs comparable in form, it was necessary to take a number of factors into consideration: (a) the total vocabulary, (b) the number of sentences, (c) the number of new words in each sentence, and (d) the total number of work items per sentence, including the number of words, the number of letters, and the number of substitutions. (a) The vocabulary of Dynamics of Mind was reduced to 88 words, that of Physiological Limit to 92, and that of Formal Introductions to 94. (b) Each paragraph was rewritten so that it contained eight sentences, each sentence constituting a task unit, with two sentences summarizing the same material for the second day's task. (c) The words in the practice period were so chosen that four new words could suffice for each sentence in each task, including those in each Sequel. Effort was made to have these words of somewhat similar difficulty. (d) The work items for each sentence included the number of words, the number of letters, and the number of necessary substitutions. It was considered important that the sum of these work items should be

about the same for every sentence of the three tasks. Accordingly minor changes were made in the materials until an approximate uniformity was reached. The sentences in Dynamics of Mind, including the Sequel, were made to average 143.3 items each with an average deviation of 1.2; those in Physiological Limit, 143.3 ± 2.1 ; and those in Formal Introductions, 143.7 ± 1.2 .

Procedure

As in the earlier experiments, the code was plainly printed and placed where the subjects could glance at it at will. Their task was to say each letter of a word aloud, then to pronounce the word, and when all the words of a sentence had thus been given separately, to read the entire sentence aloud. Each of the eight sentences constituted a task unit, and its completion was recorded on the tape by the experimenter's assistant.

Since there were three degrees of comprehensibility, five days of work were demanded of each subject. The practice materials were of especial importance in this case. After some preliminary drill on the code, the subjects read sentences similar in form to those in the regular tasks but not identical with any of them. Care was taken to give the vocabularies equal representation.

The subjects were forty-eight junior college students who had not taken part in the previous experiment in substitution.

Results

Figures 9 and 10 present the detailed results for speed and accuracy respectively.

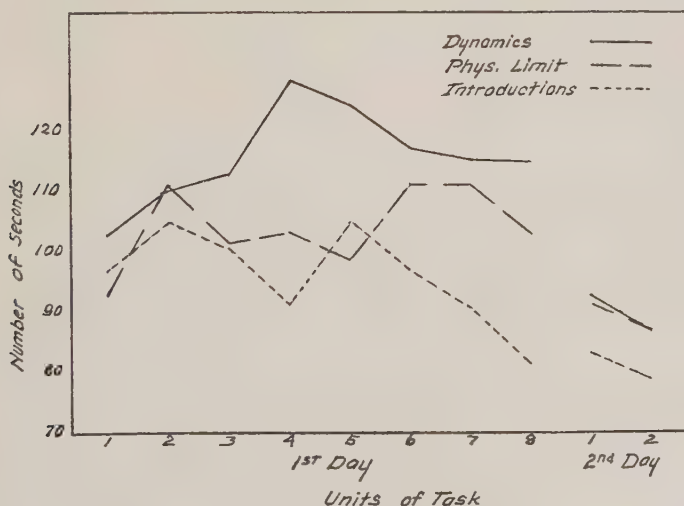


FIG. 9. Average time in seconds per unit of task for three degrees of comprehensibility.

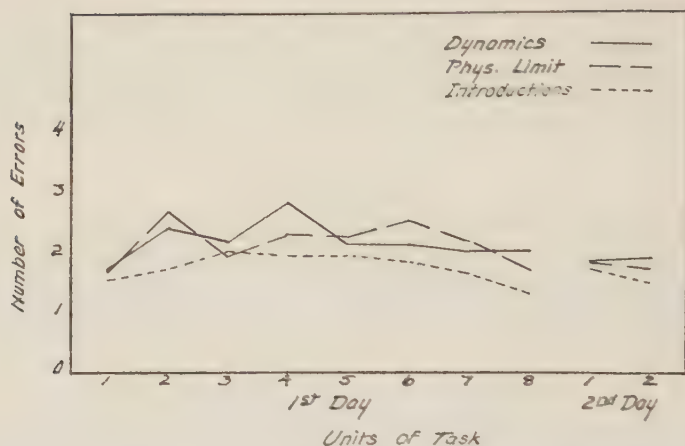


FIG. 10. Average numbers of errors per unit of task for three degrees of comprehensibility.

With the criterion of speed, striking differences appear for the three degrees of comprehensibility. Dynamics of Mind has the large decrement of 22.98 ± 2.76 ; Physiological Limit, the more moderate one of 11.23 ± 3.28 ; and Formal Introductions, none at all. As might be expected, the differences between the decrements of Dynamics of Mind and of the other tasks are highly significant. The lowest difference, that for Physiological Limit and Formal Introductions, has a critical ratio of 2.6.

With accuracy, Dynamics of Mind alone shows decrement, and even that not to a reliable degree. The tasks remain in the same order, however, as regards their effects, Formal Introductions losing most by the day's interval. No reliable differences between decrements appear with accuracy.

When time and errors are both reduced to percentages, it is found that with speed Dynamics of Mind has a decrement of 25.5 percent, and Physiological Limit one of 12.4 percent. Formal Introduction has no decrement. With accuracy, Dynamics of Mind alone shows a decrement. It is 10.3 percent.

The levels of efficiency in terms of average number of seconds per unit of task, are more conspicuous in this experi-

ment than in any of the others. Dynamics of Mind required an average of 115.89 sec.; Physiological Limit, 104.43 sec.; and Formal Introductions, only 96.28 sec. The levels for the Sequels were 89.66 sec., 89.09 sec., and 80.73 sec. respectively. With accuracy, the same relative positions are held, but the differences are less. The average for Dynamics of Mind is 2.20; for Physiological Limit, 2.18; and for Formal Introductions, 1.75. The Sequels are 1.89, 1.78, and 1.62 respectively.

Subjects' General Behavior

Of all the tasks in the experiments, Dynamics of Mind seemed to be most disliked. No one broke off in the middle of a day's work, but three subjects refused to come back for the Sequel and had to be dropped from the experiment. Several subjects made apologetic comments on their performance after this task was completed. C. H. said, "I don't know what was the matter with me today. I couldn't keep my mind on it." G. B., who had Dynamics of Mind last of the three tasks, was asked which day's work was hardest for her. She said, "This was hardest, but I guess I didn't keep my mind on it. Seemed like everything bothered me. I kept hearing noises and thinking about that machine."

With Physiological Limit, D. M. said, "I keep guessing, and sometimes I guess wrong." Similar comments were made often with this task and with Formal Introductions.

Only with the latter task, however, was any real interest shown. O. D. remarked when he had finished, "Well, I learned something from that." He and one other boy went back to the laboratory later to make sure they remembered the formulas correctly. This fact suggests that other variables as well as comprehensibility were present in these materials.

The comments of the subjects and the extremely high percentage of decrement found with the least comprehensible materials seem to the writer to indicate that the words of the paragraph, Dynamics of mind, which are quite familiar in other connections but not as they are used here, have

much the effect of discrete stimuli, perhaps even of nonsense syllables. On the other hand the remarkable freedom from decrement found with the more comprehensible materials, together with the comments quoted above and observations of the subjects' behavior, seems to indicate that ready comprehension of connected materials makes possible a forward-looking activity somewhat comparable to that which probably takes place in ordinary reading, though in these paragraphs, of course, the nature of the task precludes a broad eye-voice span.

Conclusions

1. Paragraphs read from a code are productive of a work decrement with both speed and accuracy if their degree of comprehensibility is low.
2. Comprehensibility of connected materials bears an inverse relationship to the decrement developed in the task with both speed and accuracy.
3. Levels of efficiency of performance are proportional to the comprehensibility of the task.
4. Comprehensible connected materials elicit an activity that facilitates mental work and prevents the development of decrement.

GENERAL CONCLUSIONS AND INTERPRETATIONS

Three variables in work materials in addition to repetition are found to affect the course of mental work. They are connectedness, associative value, and comprehensibility. Their effects are by no means identical.

1. Connectedness of mental work materials bears an inverse relationship to the decrement developed in the work, whether decrement is measured in terms of speed or of accuracy.
2. Very low and very high degrees of associative value in discrete materials are both productive of more decrement than is a moderate degree.
3. Comprehensibility of materials bears an inverse relationship to decrement, work with highly comprehensible materials showing no decrement at all.

4. Discrete materials and connected materials present a contrast in their effect upon the course of mental work: with discrete materials, mental work is performed with low efficiency and the development of considerable decrement, especially if the separate stimuli are very low or very high in associative value; with connected materials, mental work is performed with high efficiency and with little or no decrement, especially if the connected materials have a high degree of comprehensibility.

The earlier experiments with mental work materials, which proved indubitably that repetition is productive of decrement, were developed at a time when the reflex arc concept dominated psychological literature. Some modification of refractory phase seemed to account nicely for results. It is difficult, however, to see how refractory phase (even very liberally interpreted) can be made to explain the decrements developed with the present materials in which the principle of repetition has been rigidly controlled.

In a former paper (17), the writer (greatly influenced by the work of Carr and Lashley in their quite different fields) suggested as an alternative hypothesis that mental fatigue is a highly complex phenomenon, which must be explained not merely as resulting from the continuous exercise of a single function but in terms of the total activity of the organism. Total activity must include not only the function involved in performing the assigned task, but all the disrupting and facilitating activities, too, resulting from various central and peripheral stimuli.³ Maintaining one activity as against the others is a function of the total situation—of the general condition of the individual, of his 'volitional drive,' of the motivation involved, of the nature of the original stimulus, of the strength of the extraneous stimuli, and the like. Mental work, then, in terms of this hypothesis, is the maintenance

³ Obviously the hypothesis owes much to Carr's discussion of the adaptive act (4). "Any adaptive act is always performed in the presence of a wider sensory environment, and all aspects of this sensory situation will affect the organism and release nervous impulses that must find a motor outlet. . . . A stimulus that possesses sufficient motive power may disrupt the act and initiate an adaptive response in reference to itself. Weaker stimuli may function as distractions."

of an activity against encroaching distraction. This maintenance is usually intermittent, and blocking occurs; if prolonged, it becomes a struggle which sooner or later results in feelings of fatigue, and in a work decrement.

Obviously many of the complex factors suggested above are not now accessible to investigation. The present study has been limited to an attempt to investigate one of them—the nature of the stimulus. It is not assumed that the other factors are eliminated but on the contrary that they always interact and that systematic variation of one factor may modify (perhaps exaggerate) the facilitating or disrupting effect of the others.

It appears that not only is homogeneity⁴ unfavorable to work efficiency, but so also is a very low degree of associative value in heterogeneous discrete materials. The present hypothesis suggests that these materials are productive of very limited mental activity in themselves, and hence that activity is much subject to the disruptive effect of extraneous stimuli.⁵ It appears also that discrete materials of high associative value are likewise unfavorable to work efficiency and are productive of decrement. According to the present hypothesis, the associations themselves arouse activities and halt the progress of work.

On the other hand, connectedness of materials, especially when combined with a high degree of comprehensibility, certainly facilitates work and prevents the development of decrement. An attempt was made to gain some insight into the nature of the facilitating activity. From the fact that comprehensibility seems to be essential, and from clues gained from the subjects' behavior, it is inferred that it is a sort of anticipatory set—not so much a guessing (though guessing sometimes occurs) as an integrative, forward-looking activity that enables the subjects to 'keep their minds on' what they are doing.

Such a concept as anticipatory set is by no means new. In 1892, Sully (18) spoke of the value of 'expectant attention'

⁴ Homogeneous materials really, of course, constitute the supreme example of discrete materials of low associative value.

⁵ This point obviously needs further proof.

in reading. Woodrow (21) has shown that reaction time varies with the degree of 'adaptive attention.' Zeigarnik (11) working under Lewin's direction, found that unfinished activities were remembered much better than those that had been completed. It may be that this phenomenon, which she and Lewin (10) explain through an elaborate analysis of 'tensions,' is related to anticipatory set.

Perhaps the concept of redintegration, as Hollingworth (9) interprets it, can be evoked to account for all the variations in effect produced by the stimuli employed in this study. If work materials are discrete and have low redintegrative value, they permit distraction, and a large decrement develops. If work materials are discrete and have high redintegrative value, they disrupt work by virtue of their own redintegrative effects. If work materials are connected and are easily comprehended, they constitute a pattern which the redintegrative mechanism tends to fill out as the work progresses.

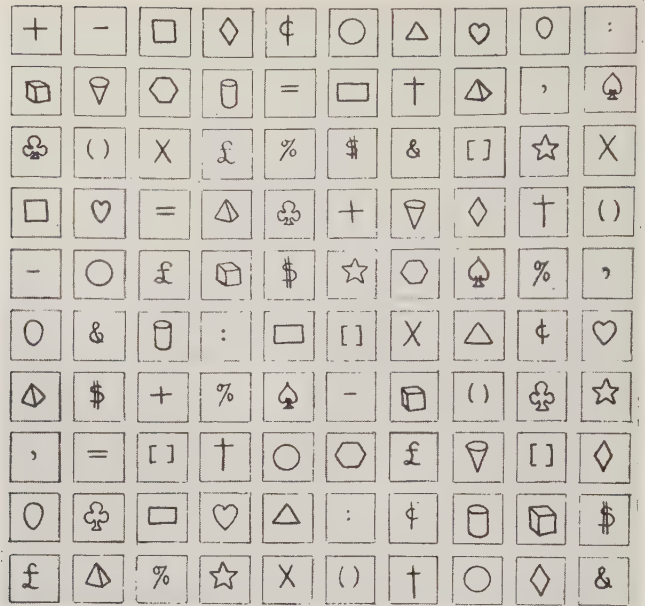
This study has attempted the investigation of the effect of three variables upon the mental work decrement. It can end only with the conclusion of Robinson and Bills (16), which was quoted above: "Other principles are also surely fundamental in the determination of the decrement, and all of them offer rich territory for exploration."

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APPENDIX PICTORIAL MATERIALS



Symbols and Forms



Objects and Animals

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